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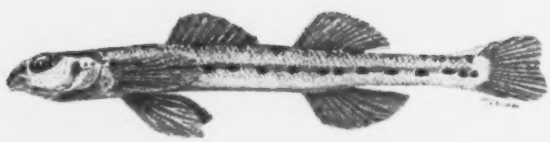
RECOVERY POTENTIAL ASSESSMENT OF EASTERN SAND DARTER (*AMMOCRYPTA PELLUCIDA*) IN CANADA



Eastern Sand Darter (Ammocrypta pellucida)
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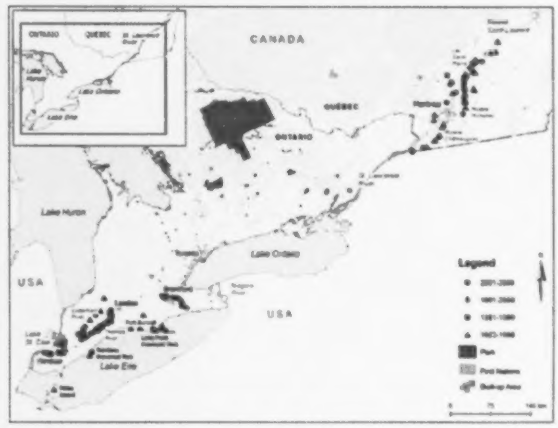

Figure 1. Distribution of Eastern Sand Darter in Canada.

Context :

*The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Eastern Sand Darter (*Ammocrypta pellucida*) in April 1994. The assessment resulted in the designation of Eastern Sand Darter as Threatened. In November 2000, the status was re-examined and confirmed by COSEWIC. This status was re-assessed in November 2009, at which time the Eastern Sand Darter range was separated into two designatable units (Ontario and Quebec populations). Both populations were designated as Threatened. The reason for designation for the two populations were quite similar, indicating that there are continuing declines the already small and fragmented populations as well as declines in the extent of occurrence for both the Ontario and Quebec populations. Eastern Sand Darter is currently listed as Threatened on Schedule 1 of the Species at Risk Act (SARA).*

A species Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to meet the various requirements of the Species at Risk Act (SARA), such as the authorization to carry out activities that would otherwise violate the SARA as well as the development of recovery strategies. The scientific information also serves as advice to the Minister of Fisheries and Oceans Canada regarding the listing of the species under SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the scientific data available with which to assess the recovery potential of Eastern Sand Darter in Canada.

SUMMARY

- In Ontario, the current and historic Eastern Sand Darter distribution is limited to three distinct areas of the Great Lakes basin: Lake Huron; Lake Erie; and, Lake St. Clair (Figure 1). Four historic locations are thought to be extirpated: Ausable River; Catfish Creek; Big Otter Creek; and, the western basin of Lake Erie. Current records exist from six sites: Lake St. Clair; Thames River; Sydenham River; Rondeau Bay; Big Creek; and, Grand River.

- In Quebec, the distribution of the Eastern Sand Darter is primarily concentrated in the St. Lawrence River and in its tributaries between Deux Montagnes Lake and Leclercville, downstream from Lake St. Pierre. In the St. Lawrence River, some specimens were recently collected in Lake St. Pierre as well as in a reach between Montreal and Sorel. The species has also been recorded in a few tributaries of six regions of the province: Montreal, Laval, Montérégie, Mauricie, Centre du Québec and Lanaudière.

- Eastern Sand Darter inhabit streams, rivers and sandy shoals in lakes in areas dominated by sandy substrate. Eastern Sand Darter have a very strong association to sand substrates, although they have been collected over various substrate types. In rivers, they are generally associated with depositional areas downstream of bends in the river and have also been associated with increased levels of dissolved oxygen. In lacustrine systems, Eastern Sand Darter were found in the nearshore on sand substrate, and are typically associated with wave-protected, sand beaches.

- In the absence of catastrophic events, the minimum viable population (MVP) size is predicted to be 323 adults. Inclusion of a 0.05, 0.10 and 0.15 probability of catastrophic decline per generation produced MVP values of 4 224, 52 822 and 595 000 respectively.

- Under current conditions, and in the absence of both, human threats and recovery efforts, a population that is 10% of these MVP values is expected to take 45 years to reach the recovery target. Depending on the recovery strategy applied and initial population size, the time to recovery varied from 14 to 50 years.

- A riverine population with 4224 adults would require at least 0.3 ha of suitable habitat, while 595 000 adults would require 41.7 ha. Lake values range from 1.72 – 240.57 ha based on the catastrophic probabilities.

- If eight discrete populations are at, or above, the minimum viable population (MVP), the risk of extinction in Canada is 5%. The risk of extinction will decrease to 2.5% with 10 recovered populations, 1% with 13 recovered populations, and 0.01% with 24 recovered populations.

- In Ontario, the greatest threats to the survival and persistence of Eastern Sand Darter is related to turbidity and sediment loading, contaminants and toxic substances, altered flow regimes and the introduction of exotic species and disease. Secondary threats include nutrient loading, barrier to movement, shoreline modifications and incidental harvest. Similar threats are negatively affecting Quebec populations; although, it is noted that Quebec populations are also facing negative effects from wave action from boats.

- Eastern Sand Darter population dynamics are particularly sensitive to perturbations affecting 0+ survival and the fertility of 1+ spawners. Harm to these life stages should be minimized to avoid jeopardizing the survival and recovery of Canadian populations.

- There remain numerous sources of uncertainty related to Eastern Sand Darter biology, ecology, life history, YOY and juvenile habitat requirements, population abundance estimates, population structure, and species distribution. A thorough understanding of the threats affecting the decline of Eastern Sand Darter populations is also lacking. Numerous threats have been identified for Eastern Sand Darter populations in Canada, although the severity of these threats is currently unknown.

BACKGROUND

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Eastern Sand Darter (*Ammocrypta pellucida*) population in Canada as Threatened in April 1994. In November 2000, this status was re-examined and confirmed by COSEWIC. This status was re-assessed in November 2009, at which time the Eastern Sand Darter range was separated into two designatable units (Ontario and Quebec populations). Both populations were designated as Threatened. Eastern Sand Darter is currently listed as Threatened on Schedule 1 of the Species at Risk Act (SARA). When COSEWIC designates an aquatic species as Threatened or Endangered and the Governor in Council decides to list it, the Minister of Fisheries and Oceans Canada (DFO) is required by the SARA to undertake a number of actions. Many of these actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including permitting on harm and recovery planning. This RPA focuses on the Eastern Sand Darter populations in Canada, and is a summary of a Canadian Science Advisory Secretariat peer-review meeting that occurred on 2-3 December 2009 in Burlington, Ontario. Three research documents, one providing background information on the species biology, habitat preferences, current status, threats and mitigations and alternatives in Ontario (Bouvier and Mandrak 2010), the second that presents this same information for Quebec (Boucher and Garceau 2010) and a third on allowable harm, population-based recovery targets, and habitat targets (Finch *et al.* 2011) provide an in-depth account of the information summarized below. Finally a proceedings document discusses the activities and key discussions of the meeting (DFO 2010). Please note that the complete reference citations have been removed from the following document to minimize the length of the document. Complete references are available at Bouvier and Mandrak (2010), Boucher and Garceau (2010) and Finch et al. (2011).

Species Description and Identification

Eastern Sand Darter (*Ammocrypta pellucida*) is a small, translucent, and elongate benthic fish. The total length of this species has been listed as 46-71 mm, averaging 64 mm, although more recently individuals up to 84 mm in length have been captured from the Grand River. The back colouration can range from faint yellow to iridescent green, while the sides can range from pale yellow to silver. A narrow metallic gold to olive-gold lateral band is common, and is generally broken by 10-14 small round or oval dark spots. The belly is silver to white. Juveniles lack any yellow colouration and are generally more silver. The first dorsal fin is spiny (8-11 weak spines) and distinctly separate from the second soft-rayed dorsal fin (9-12 rays). The fins are clear, with the exception of spawning males that exhibit black pelvic fins.

The distributions of many darters overlap with that of Eastern Sand Darter, although many distinctive characteristics help to decrease the chance of errors in identification. Eastern Sand Darter is unquestionably the most elongate of all darter species found in Canada. Also, other

darters have dorsal fins placed closer together along the dorsal surface, they lack translucent flesh, and, with the exception of the Channel Darter (*Percina copelandi*), have no small round or oval dark spots along their sides.

ASSESSMENT

Ontario - Current Species Status

Lake Huron Drainage

A historic record for this species exists for a single site in the Lake Huron drainage (Ausable River, 1928). Recent sampling throughout the Ausable River, some of which targeted Eastern Sand Darter preferred habitat, yielded no captures. It is believed that Eastern Sand Darter is extirpated from this system.

Lake St. Clair Drainage

The Thames River and Sydenham River populations represent two historic populations that have persisted. The Thames River has been the focus of many Eastern Sand Darter studies over the past five years resulting in the capture of numerous individuals. This population is considered to be the healthiest Eastern Sand Darter population in Ontario with more than 5000 individuals caught over the past 10 years. There are far fewer Eastern Sand Darter recorded from the Sydenham River (43 individuals over the past 10 years), although it should be noted that only two, one-day sampling events have targeted Eastern Sand Darter in this system.

The first capture of Eastern Sand Darter in Lake St. Clair dates back to 1979. Since this record, 268 Eastern Sand Darter have been captured in Lake St. Clair, mostly from the east and south shores. There is no record of any Eastern Sand Darter targeted sampling in this system and most captures were the result of annual monitoring programs.

Lake Erie Drainage

The presence of Eastern Sand Darter was detected in the Grand River for the first time in 1987, with the capture of more than 30 individuals. More than 735 Eastern Sand Darter have since been recorded from this system. Targeted sampling in the Grand River since 2006 has yielded greater than 66% of all recorded captures in the watershed, emphasizing the importance of targeted sampling of preferred habitat.

Although it is very difficult to assess the Eastern Sand Darter population status from both the western and central basins of Lake Erie due to limited sampling of suitable habitats, and a complete lack of targeted Eastern Sand Darter sampling, recent index trawling in the central basin at Long Point Bay suggests a decline in Eastern Sand Darter in this area.

Quebec - Current Species Status

In Quebec, the distribution of the eastern sand darter is primarily concentrated in the St. Lawrence River and in its tributaries between Deux Montagnes Lake and Leclercville, downstream from Lake St. Pierre. In the St. Lawrence River, some specimens were recently collected in Lake St. Pierre as well as in a reach between Montreal and Sorel. The species has

also been recorded in a few tributaries of six regions of the province: Montreal, Laval, Montérégie, Mauricie, Centre du Québec and Lanaudière.

The first time eastern sand darter catches were reported in Quebec was in 1941 in the Châteauguay River. Prior to 1970, the presence of the species was reported in Deux Montagnes Lake, in the Châteauguay, L'Assomption, Yamaska, St. François, Yamachiche and Gentilly rivers and in the St. Lawrence River in the area of the Lake St. Pierre archipelago near Sorel. Between 1970 and 1999, the presence of the eastern sand darter was reconfirmed in the Lake St. Pierre archipelago as well as in the Châteauguay, Yamachiche and L'Assomption rivers. At that time, there were also new reports of catches in the Richelieu, Trout, Bécancour, Aux Orignaux and Petite-Rivière-du-Chêne rivers. Specimens were also collected in the St-Lawrence River at the mouth of the Batiscan River.

Since 2000, surveys specific to the eastern sand darter have helped confirm or refute the presence of the species at certain historical sites. In addition, the species has been captured at new sites including Lake St. Pierre and the Ouareau, Milles Iles and Aux Saumon rivers (Table 1).

Table 1. Catch sites of Eastern Sand Darter in Quebec between 2000 and 2010.

Year	Stream	Sources of information
2001 :	Richelieu River (Saint-Marc-sur-Richelieu)	Vachon, 2002
	St. Lawrence River (Saint-Sulpice)	La Violette, N., unpublished data
2002 :	L'Assomption and Ouareau rivers	CARA, 2002
	Lake St. Pierre (Yamachiche, Nicolet and Notre-Dame-de-Pierreville areas)	La Violette, N., unpublished data
2003 :	Lake St. Pierre archipelago (Sainte-Anne-de-Sorel)	La Violette, N., unpublished data
	Richelieu River (Chambly)	J. Boucher, pers. comm.
	Ouareau River	Gaudreau, 2005
	Missisquoi Bay	Gaudreau 2005
2004 :	Richelieu River (Saint-Marc-sur-Richelieu)	Vachon, 2007
2005 :	Lake St. Pierre (Pointe Yamachiche)	J. April, pers. comm.
2006 :	Lake St. Pierre (Louiseville and Maskinongé areas)	La Violette, N., unpublished data
	Richelieu River (Saint-Marc-sur-Richelieu)	Vachon, 2007
	Trout River	Garceau *et al.* 2007
2007 :	Lake St. Pierre (Notre-Dame-de-Pierreville)	La Violette, N., unpublished data
	Richelieu River (Saint-Marc-sur-Richelieu)	Vachon, N., unpublished data
2008 :	Richelieu River (Saint-Marc-sur-Richelieu)	Vachon, N., unpublished data
	Aux Saumons River	D. Hatin, pers. comm.
	Des Milles Îles River	A. Boutin, pers. comm.
2009 :	Ouareau et L'Assomption rivers	C. Côté, pers. comm.
	Richelieu River (Saint-Marc-sur-Richelieu)	Vachon, N., unpublished data
2010	L'Assomption River	Blanchette, 2010

Population Status

To assess the Population Status of Eastern Sand Darter populations in Canada, each population was ranked in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory). The level of certainty was associated with each assignment (1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion). The Relative Abundance Index and Population Trajectory values were combined in the Population Status matrix to determine the Population Status for each population. Each Population Status was

subsequently ranked as Poor, Fair, Good, Unknown or Extirpated (Table 2). The Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter. Refer to Bouvier and Mandrak (2010) and Boucher and Garceau (2010) for the complete methodology on Population Status assessment.

Table 2. Population Status of all Eastern Sand Darter populations in Canada, resulting from an analysis of both the Relative Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

Population	Population Status	Certainty
ONTARIO		
Lake Huron drainage		
Ausable River	Extirpated	2
Lake St. Clair drainage		
Lake St. Clair	[redacted]	3
Thames River	Good	1
Sydenham River	[redacted]	3
Lake Erie drainage		
Western Basin	Unknown	3
Rondeau Bay	Unknown	3
Long Point Bay	[redacted]	2
Catfish Creek	Extirpated	3
Big Otter Creek	Extirpated	3
Big Creek	[redacted]	3
Grand River	Good	2
QUEBEC		
St. Lawrence River		
Montreal-Sorel Reach	[redacted]	3
Lake St. Pierre archipelago		3
Lake St. Pierre		3
St. Lawrence River tributaries		
Lake des Deux Montagnes	[redacted]	3
Des Mille Îles River	Unknown	3
St. François River	[redacted]	3
Aux Saumons River	Good	3
Richelieu River	Fair	3
Châteauguay River	[redacted]	3
Trout River	Unknown	3
Yamaska River	[redacted]	3
L'Assomption River	Fair	3
Ouareau River	Fair	3
Yamachiche River	Unknown	3
Gentilly River	Unknown	3
Bécancour River	Unknown	3
Little du Chêne River	Unknown	3
Aux Orignaux River	Unknown	3

Habitat Requirements

Spawning

Various spawning temperatures have been reported for Eastern Sand Darter ranging from 14°C to 25.5°C. Spawning has been noted to occur throughout the months of April to August. It was also noted that spawning probably occurred between late June and late July in Ontario based on gonadal examination of specimens from the Royal Ontario Museum. More recently, analysis of daily growth increments on otoliths of young-of-the-year (YOY) Eastern Sand Darter from the Thames River indicated that emergence occurred from early May to late June, requiring spawning to occur from late April to mid-June, based on a five-day incubation time. Thus, spawning in Ontario populations may occur earlier than previously estimated. Spawning has only been observed in a laboratory setting. Eastern Sand Darter from an Indiana population were observed spawning in a laboratory experiment when water temperature was between 20.5-23°C. In this laboratory experiment eggs were found buried in a mixed sand and gravel substrate. A comprehensive examination of growth, longevity, survival, maturation, fecundity, clutch and egg size for the Eastern Sand Darter population in the Thames River has now been completed (please refer to COSEWIC 2009; Finch 2009).

Larval and Juvenile

There is very limited information on larval and juvenile Eastern Sand Darter habitat requirements. It has been reported that early juveniles are more tolerant than adults of silt margins occurring in areas adjacent to coarse sand and gravel; however, another study reported that first year back-calculated growth rate in Eastern Sand Darter collected from the Thames River was lowest for individuals found in silt habitat when compared to those in sand-dominated habitats. Limited information on this life stage may be because this stage is relatively short-lived, as all fish mature the spring following hatching. Despite limited information on larval and juvenile Eastern Sand Darter, recently transformed juveniles (total length 18-23 mm) have been caught in the same habitat as adults in the Thames River, supporting the inference of habitat requirements from other well-studied life stages.

Adult

Adult Eastern Sand Darter inhabit streams, rivers and sandy shoals in lakes in areas dominated by sandy substrate. Eastern Sand Darter have a very strong association to sand substrates, although they have been collected over various substrate types. Their association with sandy substrates is most likely related to their fossorial behavior, which has been suggested to increase prey ambush efficiency and decrease energy expenditures in flowing water.

In rivers, they are generally associated with depositional areas downstream of bends in the river. It has been found that in the Thames River, Eastern Sand Darter were most often found at sites dominated by sand (0.06-2.0 mm) or fine gravel (2.0-8.0 mm), and found that they were completely absent from sites dominated by silt (<0.06 mm) or cobble (>64 mm). Conversely, a study from the Sydenham River found that Eastern Sand Darter presence was positively associated with cobble substrate, and found no association with the percent of sand. This study also noted a positive association between Eastern Sand Darter presence and flow in the Sydenham River, although flow does not seem to be an important factor in either the Grand or Thames rivers. An additional study on the Thames River reported a positive association between Eastern Sand Darter abundance and increased dissolved oxygen levels (in addition to sand substrates), concluding that habitat selection may not only be related to sand substrates

but Eastern Sand Darter may be concurrently selecting areas with preferred velocity and, therefore, higher dissolved oxygen levels. A study investigating Eastern Sand Darter growth rates reported the capture of adult Eastern Sand Darter of varying abundances within sand and silt-dominated habitats. However, unlike young-of-the-year life stages, adult growth rates were not related to substrate composition.

Shallow water depth is generally associated with Eastern Sand Darter preferred habitat, with many authors identifying a preference of <1.5 m, although this may be the result of a sampling bias related to sampling wadeable habitats. One Eastern Sand Darter report noted their capture from Lake Erie by trawling in 14.6 m of water. Recently, Eastern Sand Darter were captured by trawling in both the Grand and Thames rivers at depths ranging from 2 to 3.5 m.

In lacustrine systems, Eastern Sand Darter were found in the nearshore on sand substrate, and are typically associated with wave-protected, sand beaches.

In Quebec, many of the sites were Eastern Sand Darter were captured were described as having a dominant sand substrate, shallow water depth, slow water velocities and little to no aquatic plants.

Residence

Residence is defined in SARA as a, "dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating". Residence is interpreted by DFO as being constructed by the organism. In the context of the above narrative description of habitat requirements during YOY, juvenile and adult life stages, Eastern Sand Darter do not construct residences during their life cycle.

Recovery Targets

Recovery Targets and Times

Consistent with SARA section 73(3), demographic sustainability was used as a criterion to set recovery targets for Eastern Sand Darter. Demographic sustainability can be explained as a self-sustaining population over the long term and is related to the concept of Minimum Viable Population (MVP; Shaffer 1981). As Eastern Sand Darter is a small bodied, short-lived fish (G =1.5 years), MVP for this study was defined as minimum adult population size needed for a 95% chance of persistence over 100 years.

Simulations indicated that in the absence of catastrophic events, the minimum viable population (MVP) size is predicted to be 323 adults. Inclusion of a 0.05, 0.10 and 0.15 probability of catastrophic decline per generation produced MVP values of 4 224, 52 822 and 595 000 respectively. Under current conditions, and in the absence of both, human threats and recovery efforts, a population that is 10% of these MVP values is expected to take 45 years to reach the recovery target. Time to recovery increased exponentially as harm was applied to the composite vital rates of fertility and survival (Figure 2). Time to recovery varied between 18 to 34 years depending on the recovery scenario. Recovery times for each strategy varied with the initial percentage of MVP (Figure 3), with recovery taking 28-50 years at 2% of MVP while 20% of the MVP generated recovery times of 14-26 years. Regardless of the initial population size, the most effective scenario was when S_1 and f_2 were increased by 20% (scenario 6) while the least effective scenario only increased F_2 by 10% (scenario 3) (Figure 3).

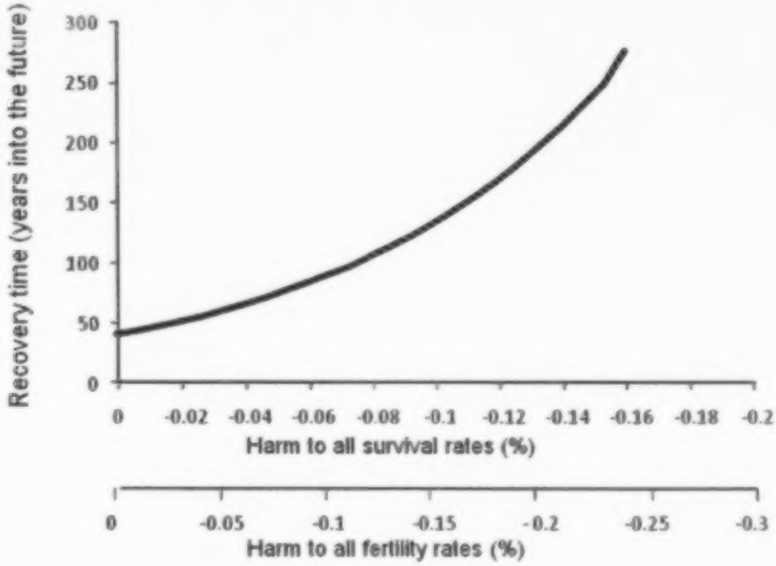

Figure 2. Predicted change in the time to 95% recovery of an Eastern Sand Darter population that is experiencing increased harm to the composite survival or fertility rates.

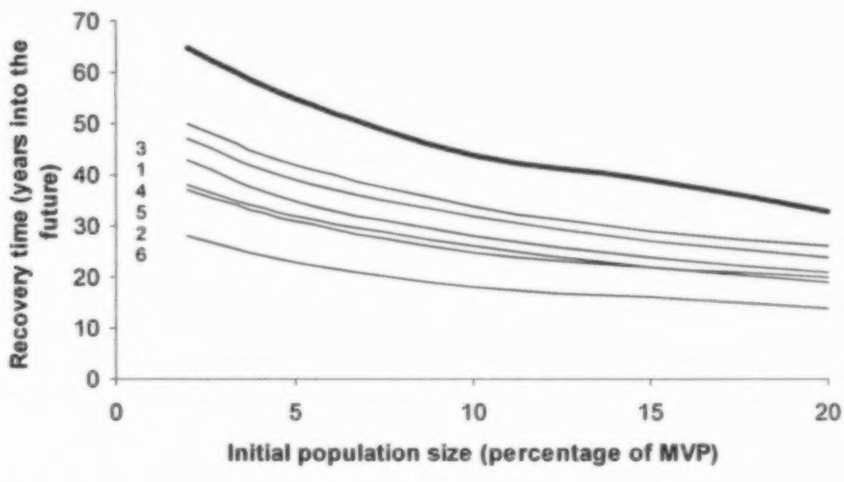

Figure 3. Projections of mean Eastern Sand Darter recovery times over a range of initial population sizes for 6 potential management scenarios. The thick line shows recovery time in the absence of mitigation or additional harm (status quo conditions). Numbered lines correspond to various recovery scenarios: 1 – added a 10% increase in the survival of 0+ individuals; 2 – added a 20% increase in the survival of 0+ individuals; 3 – added a 10% increase in the fertility of first-time spawners; 4 – added a 20% increase in the fertility of first-time spawners; 5 – added a 10% increase in the survival of 0+ individuals and a 10% increase in the fertility of first-time spawners; 6 - added a 20% increase in the survival of 0+ individuals and a 20% increase in the fertility of first-time spawners.

Minimum Area for Population Viability

Minimum area for population viability (MAPV) is a quantification of the amount of habitat required to support a viable population. Variables included in the MAPV assessment include MVP values and area required per individual (API values). Based on published allometries, with a MVP target of 4 224 adults under the probability of catastrophic decline per generation (P_k) = 0.05, the river MAPV is 0.3 ha with an upper MAPV of 41.7 ha needed to support of 595 000 adults when P_k = 0.15 (Table 3). Lake MVP values range from 1.72 – 240.57 ha based on the catastrophic probabilities. Based on densities observed in the lower Thames River (0.36 ESD/ m^2; Finch 2009), equivalent to an area per individual of 2.78 m^2, MAPV values were 1.18, 14.67 and 165.28 ha for the 0.05, 0.10 and 0.15 P_k values, respectively. While MAPV values based on the densities observed in the Grand and Thames Rivers ranged from 2.50 – 352.07 ha and 4.75 – 668.54 ha respectively (Table 3).

Table 3. Calculation of minimum area of population viability (MAPV) based on minimum viable population (MVP) values and area per individual (API) values. API river values of 0.02 m^2 and 0.18 m^2 for 0+ and adults respectively were used while lake API values were 0.12 m^2 and 0.92 m^2. Different population viability criteria included three probabilities of catastrophic decline per generation (P_k) for a 95% persistence over 100 years and Reed et al.'s (2003b) allometric calculation for 99% persistence over 40 generations. MAPV values for the Thames and Grand Rivers are based on observed densities.

Population Viability Criteria		MVP	MAPV (ha)				
		Adult	River	Lake	Thames R. 0.36 ESD/m$_2$ (Finch 2009)	Thames R. 0.09 ESD/m$_2$ (Dextrase, pers. comm)	Grand R. 0.17 ESD/m$_2$ (Dextrase, pers. comm)
95% persistence, 100 years	P_k = 0.05	4,224	0.3	1.72	1.17	4.75	2.50
	P_k = 0.1	52,822	3.7	21.36	14.67	59.35	31.26
	P_k = 0.15	595,000	41.7	240.57	165.28	668.54	352.07
99% persistence, 40G (Reed et al. 2003)	P_k = 0	1,180	0.08	0.48	0.33	1.33	0.70

Threats to Survival and Recovery

A wide variety of threats negatively impact Eastern Sand Darter across its range. The greatest threats to the survival and persistence of Eastern Sand Darter are related to the degradation and/or loss of preferred habitat. In occupied rivers, numerous activities are known to negatively affect fish habitat; however, those most commonly related to the destruction and degradation of Eastern Sand Darter habitat relate to agricultural and urban development, and result in increased turbidity, sediment loading, and siltation, increased levels of contaminants and toxic substances, and increases in nutrient loading.

Physical modifications, such as the creation of impoundments and dams, can create barriers to movement, alter flow regimes and contribute to increased sedimentation. Of particular importance to the Quebec population of Eastern Sand Darter are the fluctuating water levels of the St. Lawrence River resulting from a combination of natural factors and human interventions. The St. Lawrence River flow is influenced by the control structures used primarily to control spring flooding, to facilitate commercial navigation and for producing hydroelectric power. In addition, the dredging of the shipping channel and shoals modify the River's water levels by concentrating the flow in the main channel and reducing current speeds in the shallow parts.

Eastern Sand Darter could be particularly affected by low water levels in the St. Lawrence River. The beating of the waves against the shores of a river, stemming from passing ships, can cause bank erosion. In the St. Lawrence River, the passing of high tonnage vessels erodes the banks and accelerates silting. In the St. Lawrence freshwater reach, which is frequented by the eastern sand darter, it is estimated that wave action from passing vessels causes banks to recede up to 3 meters per year. The impact from recreational boats in smaller streams and rivers is also considerable.

Habitat loss in the form of river and lake shoreline modifications can lead to altered flow regimes and coastal processes resulting in the loss of Eastern Sand Darter preferred habitat. These factors can detrimentally affect Eastern Sand Darter populations and decrease the likelihood of recovery by fragmenting populations. Declines in Eastern Sand Darter populations may be linked to the presence of exotic species. Specifically, Round Goby in the Great Lakes may be negatively affecting Eastern Sand Darter by out-competing them for space and resources. The degree to which the baitfish industry affects Eastern Sand Darter is currently unknown, but incidental harvest associated with the baitfish industry may pose a threat to the persistence of Eastern Sand Darter populations.

It is important to note that most Eastern Sand Darter populations are facing more than a single threat, and that the cumulative impacts of multiple threats may exacerbate their decline. It is quite difficult to quantify these interactions and; therefore, each threat is discussed independently.

Threat Status

To assess the Threat Status of Eastern Sand Darter populations in Canada, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population by-population basis (see Bouvier and Mandrak 2010 and Boucher and Garceau 2010 for details). The Threat Likelihood and Threat Impact for each population were combined in the Threat Status Matrix resulting in the final Threat Status for each population (Table 4). Certainty was classified for both Threat Likelihood and Threat Impact based on: 1= causative studies; 2=correlative studies; and, 3=expert opinion. Certainty associated with the Threat Status is reflective of the lowest level of certainty associated with either initial parameter.

Table 4. Threat Status for all Eastern Sand Darter populations in Canada, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Status, which is reflective of the lowest level of certainty associated with either initial parameter (Threat Likelihood, or Threat Impact). Clear cells do not represent a lack of a relationship between a population and a threat; rather, they indicate that either the Threat Likelihood or Threat Impact was Unknown. Gray cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the population is located.

Ontario

	Lake Huron drainage	Lake St. Clair drainage		
Threats	**Ausable River**	**Lake St. Clair**	**Thames River**	**Sydenham River**
Turbidity and sediment loading	[illegible]	[illegible]	[illegible]	[illegible]
Contaminants and toxic substances	[illegible]	[illegible]	[illegible]	[illegible]
Nutrient loading	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Barriers to movement				Low (3)
Altered flow regimes	[illegible]		[illegible]	[illegible]
Shoreline modifications	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Exotic species and disease	[illegible]	[illegible]	[illegible]	[illegible]
Incidental harvest	Low (3)	Low (3)	Low (3)	Low (3)

	Lake Erie drainage			
Threats	**Western Basin**	**Rondeau Bay**	**Long Point Bay**	**Catfish Creek**
Turbidity and sediment loading	Medium (3)	[illegible]	[illegible]	[illegible]
Contaminants and toxic substances	Unknown (3)	[illegible]	Medium (3)	Unknown (3)
Nutrient loading	Low (3)	Medium (3)	Medium (3)	Medium (3)
Barriers to movement				
Altered flow regimes				[illegible]
Shoreline modifications	Medium (3)	[illegible]	Low (3)	Medium (3)
Exotic species and disease	[illegible]	[illegible]	[illegible]	[illegible]
Incidental harvest	Low (3)	Low (3)	Low (3)	Low (3)

Ontario (continued)

	Lake Erie drainage		
Threats	**Big Otter Creek**	**Big Creek**	**Grand River**
Turbidity and sediment loading	[illegible]	[illegible]	[illegible]
Contaminants and toxic substances	Unknown (3)	Unknown (3)	Medium (3)
Nutrient loading	Medium (3)	Medium (3)	Medium (3)
Barriers to movement	Medium (3)	Low (3)	Medium (3)
Altered flow regimes	Medium (3)	[illegible]	[illegible]
Shoreline modifications	Medium (3)	Medium (3)	[illegible]
Exotic species and disease	[illegible]	[illegible]	[illegible]
Incidental harvest	Low (3)	Low (3)	Low (3)

Quebec

Threats	St. Laurent River	Lake des Deux-Montagnes	Des Milles Îles River	St. François River
Barriers to movement	Low (3)	Unknown (3)	Unknown (3)	[illegible]
Altered flow regimes	Medium (2)	Unknown (3)	Unknown (3)	[illegible]
Shoreline modifications	Medium (2)	Unknown (3)	Unknown (3)	Low (3)
Turbidity and sediment loading	[illegible]	Unknown (3)	Unknown (3)	Medium (3)
Contaminants and toxic substances	Unknown (3)	Unknown (3)	Unknown (3)	Medium (3)
Nutrient loading	[illegible]	Low (3)	Unknown (3)	Low (3)
Exotic species and disease	[illegible]	[illegible]	[illegible]	Low (3)
Incidental harvest	Low (1)	Low (1)	Low (1)	Low (1)
Wave action from boats	Medium (3)	Medium (3)	Medium (3)	Low (3)

Quebec (continued)

Threats	Aux Saumons River	Richelieu River	Châteauguay River	Trout River
Barriers to movement	Low (3)	Low (3)	Low (3)	Low (3)
Altered flow regimes	Low (3)	Low (3)	Low (3)	Low (3)
Shoreline modifications	Low (3)	Medium (3)	Low (3)	Low (3)
Turbidity and sediment loading	Low (3)	Medium (3)	Medium (2)	Medium (2)
Contaminants and toxic substances	Low (3)	Medium (3)	Medium (3)	Medium (3)
Nutrient loading	Low (3)	Medium (3)	Medium (3)	Medium (3)
Exotic species and disease	Low (3)	Medium (2)	Low (2)	Low (2)
Incidental harvest	Low (1)	Low (1)	Low (1)	Low (1)
Wave action from boats	Unknown (3)	Medium (3)	Low (3)	Low (3)

Threats	Yamaska River	L'Assomption River	Ouareau River	Yamachiche River
Barriers to movement	Low (3)	Low (3)	Low (3)	Unknown (3)
Altered flow regimes	Medium (3)	Low (3)	Medium (3)	Unknown (3)
Shoreline modifications	Low (3)	Medium (2)	Medium (2)	Unknown (3)
Turbidity and sediment loading	[redacted]	Medium (2)	Medium (2)	Unknown (3)
Contaminants and toxic substances		Medium (3)	Medium (3)	Unknown (3)
Nutrient loading		Medium (3)	Medium (3)	Unknown (3)
Exotic species and disease	Unknown (2)	Unknown (3)	Unknown (3)	Unknown (3)
Incidental harvest	Low (1)	Low (1)	Low (1)	Low (1)
Wave action from boats	Low (3)	Unknown (3)	Unknown (3)	Unknown (3)

Quebec (continued)

Threats	Gentilly River	Bécancour River	Little du Chêne River	Aux Orignaux River
Barriers to movement	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)
Altered flow regimes	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)
Shoreline modifications	Unknown (3)	Medium (3)	Unknown (3)	Unknown (3)
Turbidity and sediment loading	Unknown (3)	Medium (3)	Unknown (3)	Unknown (3)
Contaminants and toxic substances	Unknown (3)	Medium (3)	Unknown (3)	Unknown (3)
Nutrient loading	Unknown (3)	Medium (3)	Unknown (3)	Unknown (3)
Exotic species and disease	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)
Incidental harvest	Low (1)	Low (1)	Low (1)	Low (1)
Wave action from boats	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)

Allowable Harm

Allowable harm was assessed in a demographic framework following Vélez-Espino and Koops (2009). This assessment uses perturbation analysis that depends on the construction of projection matrices from which population growth rate can be calculated and the relative importance of each vital rate can be used to project the effects of recovery efforts. See Finch et al. (2011) for complete details on the model and results. Modelling indicated that Eastern Sand Darter growth rate most sensitive to the survival of 0+ individuals (S_1) and the fertility of first-time spawners (f_2) (Figure 4). The wide confidence intervals associated with the vital rate estimates suggest that elasticities are sensitive to variation in clutch size, longevity and age-at-maturity. As a result, large variation was also noted in the allowable harm estimates for each vital rate. Using the upper 95% CI in a precautionary approach, our results suggest that either a 38% decrease in the annual survival rate of 0+ individuals or a 40% decrease in the fertility rate of for 1+ individual represent the maximum allowable harm for Eastern Sand Darter. Other allowable harm limits include; a 32% decrease to all survival rates or a 34% decrease to all fertility rates. Human activities causing harm in excess of these thresholds could compromise the future viability of the population.

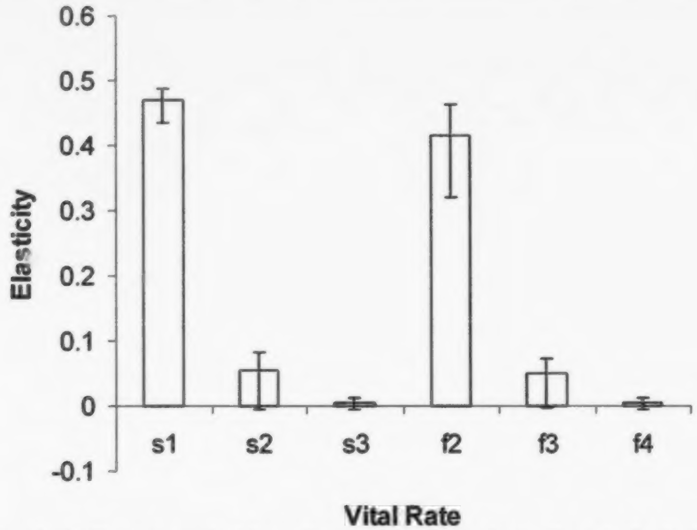

Figure 4. Vital rate elasticities generated from the stochastic analysis. Bars indicate the 95% confidence intervals for each survival (S_i) and fertility (f_i) probability.

Summary of Science Advice on Allowable Harm

- When population trajectory is declining there is no scope for allowable harm.
- When population trajectory and/or abundance is unknown the scope for allowable harm can only be assessed once population data are collected.
- Scientific research to advance the knowledge required to support the recovery of the species should be allowed.
- Populations are particularly susceptible to harm related to the survival of 0+ individuals (S_1) and the fertility of first-time spawners (f_2) and any harm should be minimized.
- If population abundance estimates exceed MVP, cumulative allowable harm might be allowed to the level identified in the allowable harm modeling

Mitigations and Alternatives

Numerous threats affecting Eastern Sand Darter populations are related to habitat loss or degradation. Habitat-related threats to Eastern Sand Darter have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 5). DFO-FHM has developed guidance on generic mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Ontario Great Lakes Area (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies. Additional mitigation and alternative measures, specific to exotic species and incidental harvest through the baitfish industry, are listed below.

Table 5. Threats to Eastern Sand Darter populations and the Pathways of Effect associated with each threat. 1 - Vegetation clearing; 2 – Grading; 3 – Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site.

Threats	Pathway(s)
Turbidity and sediment loading	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18
Contaminants and toxic substances	1, 4, 5 ,6 ,7 ,11 ,12 ,13 ,14, 15, 16 ,18
Nutrient loading	1, 4, 7, 8, 11, 12, 13, 14, 15, 16
Barriers to movement	10, 16, 17
Altered flow regimes	10, 11, 12, 16, 18
Shoreline modifications	1, 2, 3, 4, 5, 7, 8, 10, 11, 13, 16, 18

Exotic Species and Disease

Round Goby introduction and establishment could have negative effects on Eastern Sand Darter populations.

Mitigation

- Removal/control of non-native species from areas known to be inhabited by Eastern Sand Darter.
- Establish "Safe Harbours" in areas known to have suitable Eastern Sand Darter habitat.
- Watershed monitoring for exotic species that may negatively affect Eastern Sand Darter populations, or negatively affect Eastern Sand Darter preferred habitat.
- Develop plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an exotic species.
- Prohibition of the use of live baitfish in areas known to be inhabited by Eastern Sand Darter.
- Prohibit the introduction of dead baitfish in areas known to be inhabited by Eastern Sand Darter to minimize the spread of disease.
- Introduction of a public awareness campaign.
- Use of barriers to prevent the colonization of exotic species in areas where Eastern Sand Darter are present.
- Under circumstances where barriers to fish movement (i.e., dams) are to be removed or fish passage is to be increased (i.e., creation of a fishway) the potential negative effects of invasive species moving into Eastern Sand Darter habitat should be considered.

Alternatives

- Unauthorized introductions
  - None.
- Authorized introductions
  - Do not carry out introduction where Eastern Sand Darter is known to exist.

Incidental Harvest

Incidental harvest of Eastern Sand Darter through the baitfish industry was recognized as a potentially low risk threat.

Mitigation
- Provide information and education to bait harvesters on Eastern Sand Darter, and request the voluntary avoidance of occupied Eastern Sand Darter areas.
- Immediately release Eastern Sand Darter if incidentally caught.

Alternatives
- Prohibition of the harvest of baitfish in areas where Eastern Sand Darter is known to exist.
- Acquire (buy out) bait harvest licenses where Eastern Sand Darter is known to exist.
- Restrict gear type used to catch baitfish to minimize the probability of Eastern Sand Darter capture.

Sources of uncertainty

Despite a few recent studies on Eastern Sand Darter in Ontario, there remain key sources of uncertainty for this species. There is a need for quantitative sampling of Eastern Sand Darter in areas where they are known to occur to determine population size, trajectory and trends over time. There is also a need for targeted sampling of historic sites in both the western and central basins of Lake Erie to determine Eastern Sand Darter persistence or extirpation. The Eastern Sand Darter population of Big Creek was once thought to be extirpated; however, three individuals were captured from this area in 2008. Targeted sampling at known sites of capture should be completed in this system to determine population size. In Quebec, Eastern Sand Darter has never been the subject of an in-depth study and significant sources of uncertainty still exist. The recent discovery of the eastern sand darter in new streams and rivers such as the Mille Iles, Aux Saumons and Ouareau rivers, shows that the species' distribution range has not yet been precisely defined in Quebec. Acquiring knowledge on the eastern sand darter distribution, abundance and population trends is thus critical. There is also a priority to conduct surveys to confirm or refute the presence of the species in historical catch sites

Additional sampling is also necessary for all populations with low certainty identified in the population status analysis. These baseline data are required to monitor Eastern Sand Darter distribution and population trends as well as the success of any recovery measures. There is a need to assess genetic variation across all Eastern Sand Darter populations in Canada to determine population structure.

The current distribution and extent of suitable Eastern Sand Darter habitat should be investigated and mapped. These areas should be the focus of future targeted sampling efforts for this species. There is also a need to identify habitat requirements for each life stage. There is very little information available for both larval and juvenile habitat requirements necessitating the inference of these requirements from other, well-studied, life stages. Larval surveys are needed to identify both spawning and nursery grounds. Also, targeted sampling should occur in areas with water depth greater than 1.5 m to determine Eastern Sand Darter prefer shallow water or if this is a sampling artifact.

Variables required to inform the population modeling efforts are currently unknown for Eastern Sand Darter populations in Canada, creating the need to use data from other non-Canadian populations. Additional studies are needed to fill in these knowledge gaps and should focus on

acquiring additional information population growth rate, population structure, clutch size and fecundity. In terms of basic biology, there is also a need to determine physiological parameter limits including temperature, pH, dissolved oxygen and pollution tolerance.

Numerous threats have been identified for Eastern Sand Darter populations, although the severity of these threats is currently unknown. There is a need for more causative studies to evaluate the impact of each threat on each Eastern Sand Darter population with greater certainty. A greater knowledge of the effects of siltation on Eastern Sand Darter populations and spawning areas is required. Eastern Sand Darter is considered to be a pollution-intolerant species (Barbour *et al.* 1999), although there is a lack of evidence on the direct or indirect effects of toxic substances on Eastern Sand Darter populations. There is a need to determine threshold levels for water quality parameters (e.g., nutrients, dissolved oxygen). The threat from Round Goby is inferred from studies on other benthic fishes, and preliminary correlative analysis. Additional research is needed to determine the direct and indirect effects that Round Goby will have on Eastern Sand Darter populations. Incidental harvest through the baitfish industry may also play a role in the decline of Eastern Sand Darter, although the degree to which this threat is affecting Eastern Sand Darter populations is still unknown. Quantification of the impact from threats is required for the purposes of calculating allowable harm and for identifying threshold values for specific threats.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Zonal Advisory Meeting of December 2-3, 2009 on Recovery Potential Assessment (RPA) for Eastern Sand Darter. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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